Translation from Japanese

(12) OFFICIAL GAZETTE FOR UNEXAMINED PATENT APPLICATIONS (A)

(11) Japanese Unexamined (Kokai) Patent Application No. **Hei 07-309850**

(19) Japanese Patent Office (JP)

(43) Publication Date: November 28, 1995

(51) Int. Cl.^{6} Identification Nos.: Internal Filing Nos.: FI: Tech. Ind.

Int. Cl.^{6}	Identification Nos.:	Internal Filing Nos.:	FI:	Tech. Ind.
C 07 D 263/24				
413/04	215			
	307			
413/12	237			
	239			

Request for Examination: Not yet submitted

Number of Claims: 17 FD

(Total of 30 pages) continued on last page

---

(21) Application No.: Hei 6-124716

(22) Application Date: May 16, 1994

---

(71) Applicant: Canon Corp. (000001007)
30-2 Shimomaruko 3-chome, Ota-ku, Tokyo

(72) Inventor: Takashi Iwaki
Canon Corp.
30-2 Shimomaruko 3-chome, Ota-ku, Tokyo

(72) Inventor: Takao Takiguchi
[same address]

(72) Inventor: Goji Tokano
[same address]

(74) Agent: Yoshio Toyota, Patent Attorney (and 1 other)

(continued on last page)

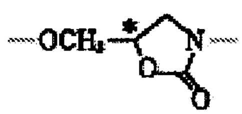
(54) Title of the Invention

Optically Active Compound, Liquid Crystal Composition Containing the Same, Liquid Crystal Element Having The Same and Display Method and Display Device Using the Same

(57) [Abstract]

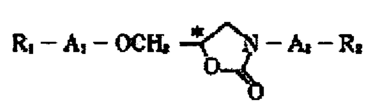
[Object:] To offer an optically active compound having good ability to effect spontaneous polarization in ferroelectric liquid crystals, high-speed response, low temperature dependence of response speed and capacity for providing high contrast, and a ferroelectric liquid crystal element using the same.

[Constitution] An optically active compound having a specific structure comprising an oxazolidinone ring represented by the following formula, where "*" denotes optical activity. A ferroelectric liquid crystal element that is constituted by means of using this optically active compound.



[Claims]

[Claim 1] An optically active compound represented by general formula (I) below:



[in the formula, R_1 and R_2 denote H, a halogen, CN or a linear, branched or cyclic alkyl group with a carbon number of 1-30, where one, or two or more non non-adjacent CH_2 groups in said alkyl group may be substituted with -O-, -S-, -CO-, -COO-, -OCO-, -CH=CH- or -C//triple bond//C-, and a hydrogen atom in said alkyl group may be changed to a fluorine atom; A_2 denotes a 1,4-phenylene, 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, 2,6-naphthylene, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-

3,6-diyl, benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, benzofurane-2,5-diyl, benzofurane-2,6-diyl, quinoxaline-2,6-diyl, quinoline-2,6-diyl, indane-2,5-diyl, 2-alkylindane-2,5-diyl (where the alkyl group is a linear or branched alkyl group with a carbon number of 1-18), indanone-2,6-diyl, 2-alkylindanone-2,6-diyl (where the alkyl group is a linear or branched alkyl group with a carbon number of 1-18), coumaran-2,5-diyl or 2-alkylcoumaran-2,5-diyl (where the alkyl group is a linear or branched alkyl group with a carbon number of 1-18); A_1 denotes A_2, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl and "*" denotes optical activity].

[Claim 2] The optically active compound according to claim 1, wherein the compound represented by general formula (I) above is any of compounds (Ia) to (Ic).

(Ia) Optically active compounds wherein A_1 is 1,4-phenylene, 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-3,6-diyl, indane-2,5-diyl, coumaran-2,5-diyl, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl and A_2 is selected from 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN.

(Ib) Optically active compounds wherein A_1 is 1,4-phenylene, 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-3,6-diyl, indane-2,5-diyl, coumaran-2,5-diyl, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl and A_2 is selected from pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl and pyridazine-3,6-diyl.

(Ic) Optically active compounds wherein A_1 is 1,4-phenylene or 1,4- phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-3,6-diyl, indane-2,5-diyl, coumaran-2,5-diyl, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl and A_2 is selected from 2,6-naphthylene, benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, quinoxaline-2,6-diyl,

quinoline-2,6-diyl, indane-2,5-diyl, 2-alkylindane-2,5-diyl, coumaran-2,5-diyl and 2-alkylcoumaran-2,5-diyl.

[Claim 3] The optically active compound according to claim 1, wherein the compounds represented by general formula (I) above are any of those of (Iaa) to (Icb).

(Iaa) Optically active compounds wherein A_1 is a 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, and A_2 is 1,4-phenylene or 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN.

(Iab) Optically active compounds wherein A_1 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, 1,4-cyclohexylene or 1,3-dioxane-2,5-diyl, and A_2 is 1,4-phenylene or 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN.

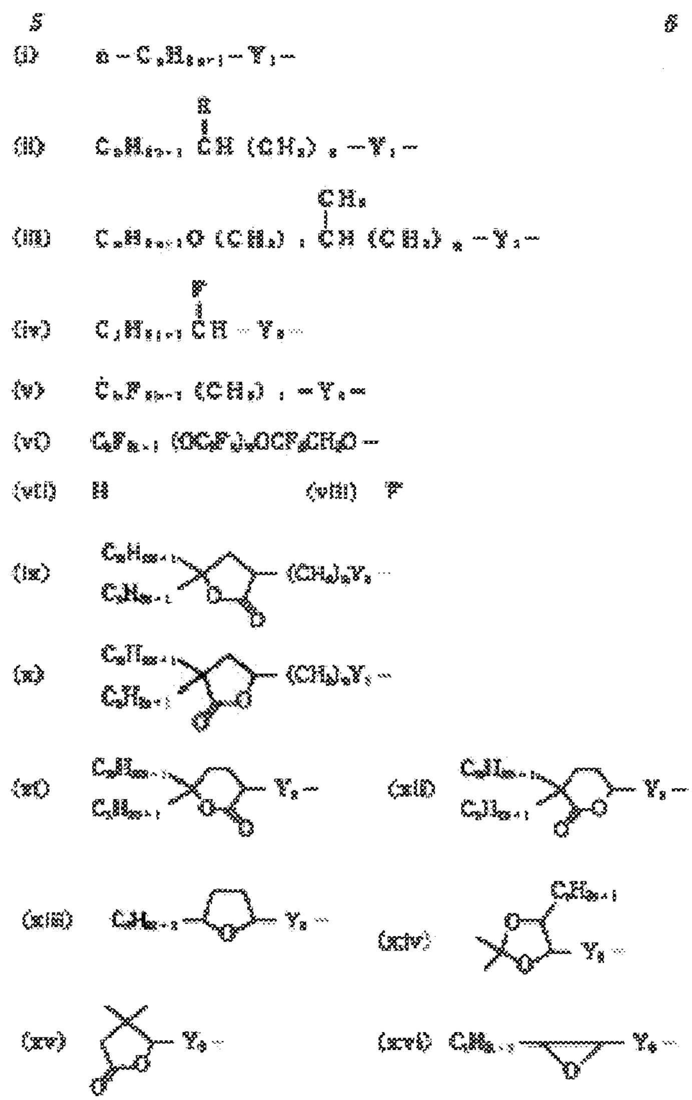
(Iba) Optically active compounds wherein A_1 is 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, and A_2 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiazole-2,5-diyl, pyrazine-2,5-diyl or pyridazine-3,6-diyl.

(Ibb) Optically active compounds wherein A_1 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, indane-2,5-diyl, coumaran-2,5-diyl, pyrazine-2,5-diyl, 1,4-cyclohexylene or pyridazine-3,6-diyl and A_2 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, pyrazine-2,5-diyl or pyridazine-3,6-diyl.

(Ica) Optically active compounds wherein A_1 is 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, and A_2 is 2,6-naphthylene, benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, quinoxaline-2,6-diyl or quinoline-2,6-diyl.

(Icb) Optically active compounds wherein A_1 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, 1,4-cyclohexylene, pyrazine-2,5-diyl or pyridazine-3,6-diyl and A_2 is 2,6-naphthylene, benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, quinoxaline-2,6-diyl or quinoline-2,6-diyl.

[Claim 4] The optically active compounds according to any of claims 1,3, characterized in that R_1 and R_2 of the optically active compounds represented by general formula (I) above are any of (i) to (xvi).



(a denotes an integer from 1 to 16, d, g and i denote 0 or integers from 1 to 7, b, e, h, j and k denote integers from 1 to 10, f, and w denote 0 or 1, and m, n, q, r, s and t denote 0 or integers from 1 to 10, where the conditions $b+d \leq 16$, $e+f+g \leq 16$ and $h+i \leq 16$ are satisfied, E denotes CH_3 or CF_3, Y_1 denotes a single bond, -O-, -COO- or -OCO-, Y_2 denotes -COO-, $-CH_2O-$, $-CH_2CH_2O-$, $-CH_2CH_2CH_2O-$ or $-CH_2CH_2-$ and Y_3 denotes a single bond, -COO-, $-CH_2O-$, -OCO- or $-OCH_2-$, and optical activity may be present).

[Claim 5] A liquid crystal composition, characterized by comprising at least one type of the optically active compound according to any of claims 1-4.

[Claim 6] The liquid crystal composition according to claim 5, characterized by comprising 1-80 wt% of the aforementioned optically active compound.

[Claim 7] The liquid crystal composition according to claim 5, characterized by comprising 1-60 wt% of the aforementioned optically active compound.
[Claim 8] The liquid crystal composition according to claim 5, characterized by comprising 1-40 wt% of the aforementioned optically active compound.
[Claim 9] The liquid crystal composition according to any of claims 5-8, characterized by having a chiral smectic phase.
[Claim 10] A liquid crystal element, characterized in that the liquid crystal composition according to any of claims 5-9 is disposed between a pair of electrode substrates.
[Claim 11] The liquid crystal element according to claim 10, characterized in that an alignment control layer is additionally provided on said electrode substrate on the side that is in contact with the liquid crystal composition.
[Claim 12] The liquid crystal element according to claim 11, wherein said alignment control layer is a layer that has been subjected to a laving treatment.
[Claim 13] The liquid crystal elements according to any of claims 10-12, characterized in that said pair of electrode substrates is disposed at a film thickness whereby the helicity of the liquid crystal molecules is released.
[Claim 14] A display method, characterized in that display is carried out by controlling the liquid crystal composition of any of claims 5-9.
[Claim 15] A display device, characterized in that liquid crystal elements according to any of claims 10-13 are provided as display elements.
[Claim 16] The display device according to claim 15, characterized by having a drive circuit for the liquid crystal elements.
[Claim 17] The display device of claims 15 or 16, characterized by having a light source.
[Detailed description of the invention]
[0001]
[Field of industrial utilization] The present invention relates to novel optically active compounds, liquid crystal compositions comprising the same and liquid crystal elements and display devices that employ the same. In additional detail, the present invention relates to novel liquid crystal compositions in which the response characteristics with respect to electrical fields is improved, liquid crystal display elements that employ the

same, liquid crystal elements that are utilized in liquid crystal-optical shutters and the like, and display devices that employ the aforementioned liquid crystal elements for display.

[0002]

[Prior art] In the past, liquid crystals have been utilized in various fields as electro-optical elements. Most of the liquid crystal elements utilized at present are TN (twisted nematic) liquid crystals as described, for example, by J. Schadt and W. Helfrich in *Applied Physics Letters* Vol. 18, Nos. 4 (1971, 2/15), pp. 127-128 "Voltage-Dependent Optical Activity of a Twisted Nematic Liquid Crystal." These elements are based on the dielectric alignment effect of liquid crystals, and effects are utilized whereby, due to the dielectric anisotropy of the liquid crystal molecules, the mean molecular axis direction orients in a particular direction under an electric field. The limit of the optical response speed of these elements is said to be on the level of milliseconds, which is too slow for many applications. In response to the development of large-size flat displays, on the other hand, driving by means of a simple matrix format has become predominant in consideration of cost, productivity and other factors in conjunction. In simple matrix formats, an electrode structure is used in which scanning electrodes and data electrodes are constituted in the form of a matrix, and a multiplex driving scheme is adopted wherein the matrix is driven so that the address signals are sequentially, periodically and selectively applied to the scanning electrodes, where specific data signals are synchronized with the address signals, and are selectively applied in parallel to the signal electrodes.

[0003] However, when the TN liquid crystal referred to above is used for the elements in this type of drive format, a specific electric field is applied to regions in which the scanning electrodes are selected and the signal electrodes are not selected or regions in which the scanning electrodes are not selected and the data electrodes are selected (referred to as "half-selected points"). If the difference between the voltage applied to the selected points and the voltage applied to the half-selected points is sufficiently large, and the voltage threshold required for vertical orientation of liquid crystal molecules in the electric field is set at an intermediate voltage value, then the display electrode will operate properly. However, as the number of scanning lines (N) is increased, the time (duty time) at which an effective electric field is applied to a single selected point during scanning of an entire screen (1 frame) will decrease by the ratio 1/N. For this reason, the voltage

differential in terms of effective voltage applied to selected points and non-selected points during repeated scanning decreases as the number of scanning lines increases. As a result, there is the disadvantage that image contrast is reduced and cross-talk is difficult to avoid.

[0004] This phenomenon arises when a liquid crystal that is not bistable (liquid crystal molecules are oriented horizontally with respect to the electrode surface in their stable state, and are oriented vertically only when an effective electric field is applied) is driven (i.e., repeatedly scanned) using a time storage effect.

[0005] In order to resolve this problem, voltage averaging, two-frequency driving, multiple matrices and other methods have been proposed in the past, but none of these methods has been adequate. Increases in size and detail of display elements has thus produced circumstances in which a ceiling has been reached that does not allow for adequate increases in scanning line number.

[0006] A means for addressing these problems with conventional liquid crystal elements is the use of liquid crystal elements having bistability offered by Clark and Lagerwal (Japanese Unexamined Patent Application No. Sho 56-107216 and the specification of U.S. Patent No. 4367924).

[0007] Ferroelectric liquid crystals having chiral smectic C phases (S^*_C phases) or H phases (S^*_H phases) have generally been used as bistable liquid crystals. These ferroelectric liquid crystals have bistability comprising a first optically stable condition and a second optically stable condition with respect to an electrical field. Consequently, in contrast to optically modulated elements used in the aforementioned TN liquid crystals, for example, the liquid crystal orients in a first optically stable condition with respect to a one electrical field vector, and also orients in a second optically stable condition with respect to a different electrical field vector. In addition, this type of liquid crystal has properties whereby it assumes either of the above two stable conditions in response to an applied electrical field, and maintains this condition when the electrical field is not applied (bistable).

[0008] In addition to the above bistable characteristics, ferroelectric liquid crystals also have excellent characteristics related to high-speed response. These characteristics result from transition of orientation states induced by direct interaction of the applied electric field and spontaneous polarization of the ferroelectric liquid crystal. Thus, the response

speed resulting from dielectric anisotropy and the electric field is faster by 3-4 orders of magnitude.

[0009] Ferroelectric liquid crystals thus have extremely superior characteristics that are latently present, and by employing these types of properties, fairly substantial improvements are gained with respect to many of the aforementioned problems with conventional TN elements. In particular, applications in high-speed optical light shutters or high-density large-scale displays can be envisioned. It is for this reason that a wide body of research has been produced concerning liquid crystal materials having ferroelectric properties. However, at present, ferroelectric liquid crystal materials that have been developed heretofore have not had adequate characteristics for use in liquid crystal elements while providing low-temperature operation capacity, high-speed response and good contrast, among other properties.

[0010] The relationship indicated in formula (1) below holds between response time τ and the magnitude of spontaneous polarization P_S:

[0011]

$$\tau = \eta/P_S \cdot E \qquad (1)$$

(where E denotes the applied electric field).

Consequently, in order to increase response time, the following methods may be used:

(i) increasing the magnitude of spontaneous polarization P_S,

(ii) decreasing viscosity η, or

(iii) increasing the applied electrical field E. However, the applied electrical field has an upper limit since it is driven by an integrated circuit or other device, and it is thus desirable for the electric field to be as low as possible. Consequently, it is necessary to decrease the viscosity η or to increase the magnitude of spontaneous polarization Ps. In ferroelectric, chiral, smectic liquid crystal compounds that have high spontaneous polarization, the internal electric field in cells undergoing spontaneous polarization is generally large, and this tends to increase restrictions on element constitutions that will allow production of bistable conditions. If the spontaneous polarization is needlessly large, on the other hand, then the viscosity will tend to increase and no appreciable increase in response speed will occur.

[0012] In addition, when the range of operating temperatures of an actual display is about 5-40°C, for example, the change in response speed will generally be as much as about 20x, which currently exceeds the limits of adjustment using drive voltage and frequency.

[0013] With liquid crystal elements in which the index of refraction of the liquid crystal is employed, the index of refraction under crossed-Nicol conditions is expressed by formula (2) below.

[0014]

$$\frac{I}{I_0} = \sin^2 4\theta_a \sin^2 \frac{\Delta n d}{\lambda} \pi$$

[0015] In formula (2), I_0 denotes the incident light intensity, I denotes the transmitted light intensity, θ_a denotes the apparent tilt angle defined below, Δn denotes the refractive index anisotropy, d denotes the liquid crystal layer film thickness, and λ denotes the wavelength of the incident light. The apparent tilt angle θ_a in the aforementioned non-helical structure thus is expressed as the angle of the average molecular axis of the liquid crystal molecules with twisted alignments in the first and second orientation condition. According to formula (2), maximum transmittance occurs when the apparent tilt angle θ_a is at 22.5°, and it is necessary for the apparent tilt angle θ_a to be as close to 22.5 as possible in non-helical structures that exhibit bistability.

[0016]

[Means for solving the problems] However, when such materials are utilized in the non-helical ferroelectric liquid crystals exhibiting bistablity developed by Clark and Lagerwal described above, problems of the type described below occur, which are factors in decreasing contrast.

[0017] Firstly, the apparent tilt angle θ_a (1/2 of the angle of the molecular axes in the two stable conditions) in non-chiral ferroelectric liquid crystals obtained by orientation using a conventional rubbed polyimide film is small relative to the tilt angle of ferroelectric liquid crystals (angle θ which is ½ the apex angle of the cone indicated in Figure 4 below). As a result, the transmittance is low. Secondly, although the contrast is high in the static condition in which an electric field is not applied, when driving the display by applying

voltage, the liquid crystal molecules fluctuate under the extremely small electric field occurring during the non-selected period, and thus darkness is reduced.

[0018] As described above, in order to achieve practical use of ferroelectric liquid crystal elements, it is necessary to use a liquid crystal composition exhibiting high-speed response, low temperature dependence of response speed and a chiral smectic phase with high contrast. In addition, it is necessary to optimize aspects related to uniform display switching, good viewing angle characteristics, low-temperature storage properties, liquid crystal composition spontaneous polarization for reducing driver IC load, chiral smectic C phase pitch, cholesteric pitch, temperature range of the liquid crystal phase, optical anisotropy, tilt angle and dielectric anisotropy.

[0019] The object of the present invention is to allow the actual implementation of ferroelectric liquid crystal elements by offering an effective optically active compound that has a high capacity for providing spontaneous polarization, high-speed response, low temperature dependence of response speed and high contrast and a liquid crystal composition containing the same. In particular, the object is to provide a ferroelectric chiral smectic liquid crystal composition and a liquid crystal element and display device that employ the aforementioned liquid crystal composition.

[0020]

[Means for solving the problems] The present invention offers an optically active compound represented by general formula (I) below:

[0021]

[0022]

[in the formula, R_1 and R_2 denote H, a halogen, CN or a linear, branched or cyclic alkyl group with a carbon number of 1-30, where one, or two or more non non-adjacent CH_2 groups in said alkyl group may be substituted with -O-, -S-, -CO-, -COO-, -OCO-, -CH=CH- or -C//triple bond//C-, and a hydrogen atom in said alkyl group may be changed to a fluorine atom; A_2 denotes a 1,4-phenylene, 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, 2,6-naphthylene, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-

3,6-diyl, benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, benzofurane-2,5-diyl, benzofurane-2,6-diyl, quinoxaline-2,6-diyl, quinoline-2,6-diyl, indane-2,5-diyl, 2-alkylindane-2,5-diyl (where the alkyl group is a linear or branched alkyl group with a carbon number of 1-18), indanone-2,6-diyl, 2-alkylindanone-2,6-diyl (where the alkyl group is a linear or branched alkyl group with a carbon number of 1-18), coumaran-2,5-diyl, 2-alkylcoumaran-2,5-diyl (where the alkyl group is a linear or branched alkyl group with a carbon number of 1-18); A_1 denotes A_2, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl; and "*" denotes optical activity]

a liquid crystal element in which the aforementioned liquid crystal composition is disposed between a pair of electrode substrates and a display method and display device employing the same.

[0023] Compounds among the optically active compounds represented by general formula (I) above that are preferred from the standpoint of liquid crystal phase temperature range, miscibility, viscosity and orientation, among other factors, are (Ia) to (Ic).

[0024]

(Ia) Optically active compounds wherein A_1 is 1,4-phenylene, 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-3,6-diyl, indane-2,5-diyl, coumaran-2,5-diyl, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl and A_2 is selected from 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN.

[0025]

(Ib) Optically active compounds wherein A_1 is 1,4-phenylene, 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-3,6-diyl, indane-2,5-diyl, coumaran-2,5-diyl, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl and A_2 is selected from pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl and pyridazine-3,6-diyl.

[0026]

(Ic) Optically active compounds wherein A_1 is 1,4-phenylene, 1,4- phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiophene-2,5-diyl, thiazole-2,5-diyl, thiadiazole-2,5-diyl, pyrazine-2,5-diyl, pyridazine-3,6-diyl, indane-2,5-diyl, coumaran-2,5-diyl, 1,4-cyclohexylene, 1,3-dioxane-2,5-diyl or 1,3-dithiane-2,5-diyl and A_2 is selected from 2,6-naphthylene, benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, quinoxaline-2,6-diyl, quinoline-2,6-diyl, indane-2,5-diyl, 2-alkylindane-2,5-diyl, coumaran-2,5-diyl and 2-alkylcoumaran-2,5-diyl.

[0027]

(Iaa) to (Icb) are provided as additionally desirable compounds.

[0028]

(Iaa) Optically active compounds wherein A_1 is a 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, and A_2 is 1,4-phenylene or 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN.

[0029]

(Iab) Optically active compounds wherein A_1 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, 1,4-cyclohexylene or 1,3-dioxane-2,5-diyl, and A_2 is 1,4-phenylene or 1,4-phenylene substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN.

[0030]

(Iba) Optically active compounds wherein A_1 is 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, and A_2 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, thiazole-2,5-diyl, pyrazine-2,5-diyl or pyridazine-3,6-diyl.

[0031]

(Ibb) Optically active compounds wherein A_1 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, indane-2,5-diyl, coumaran-2,5-diyl, pyrazine-2,5-diyl, 1,4-cyclohexylene or pyridazine-3,6-diyl and A_2 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, pyrazine-2,5-diyl or pyridazine-2,5-diyl [*sic*; conflicts with claims where compound is pyridazine-3,6-diyl].

[0032]

(Ica) Optically active compounds wherein A_1 is 1,4-phenylene or 1,4-phenylene that is substituted with one or two of F, Cl, Br, CH_3, CF_3 or CN, and A_2 is 2,6-naphthylene,

benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, quinoxaline-2,6-diyl or quinoline-2,6-diyl.

[0033]

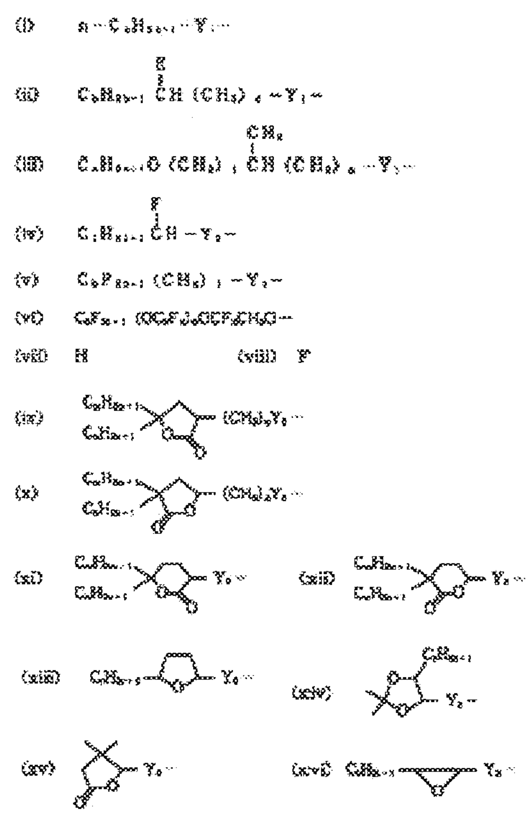
(Icb) Optically active compounds wherein A_1 is pyrimidine-2,5-diyl, pyridine-2,5-diyl, 1,4-cyclohexylene, pyrazine-2,5-diyl or pyridazine-3,6-diyl and A_2 is 2,6-naphthylene, benzothiazole-2,5-diyl, benzothiazole-2,6-diyl, benzoxazole-2,5-diyl, benzoxazole-2,6-diyl, quinoxaline-2,6-diyl or quinoline-2,6-diyl.

[0034]

When the optically active compound represented by general formula (I) above is a 1,4-phenylene having one or two substituents, preferred substituents are F, Cl, Br and CF_3, with F being additionally desirable.

[0035] R_1 and R_2 are preferably selected from (i) to (xvi) below.

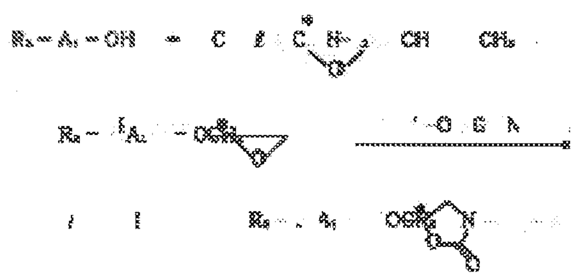
[0036]



(a denotes an integer from 1 to 16, d, g and i denote 0 or integers from 1 to 7, b, e, h, j and k denote integers from 1 to 10, f, and w denote 0 or l, m, n, q, r, s and t denote 0 or integers from 1 to 10, where the conditions $b+d \leq 16$, $e+f+g \leq 16$ and $h+i \leq 16$ are satisfied, E denotes CH_3 or CF_3, Y_1 denotes a single bond, -O-, -COO- or -OCO-, Y_2 denotes -COO-, $-CH_2O-$, $-CH_2CH_2O-$, $-CH_2CH_2CH_2O-$ or $-CH_2CH_2-$ and Y_3 denotes a single bond, -COO-, $-CH_2O-$, -OCO- or $-OCH_2-$, and optical activity may be present).

[0038] An example of a synthesis method for the optically active compounds represented by general formula I above is presented below.

[0039]

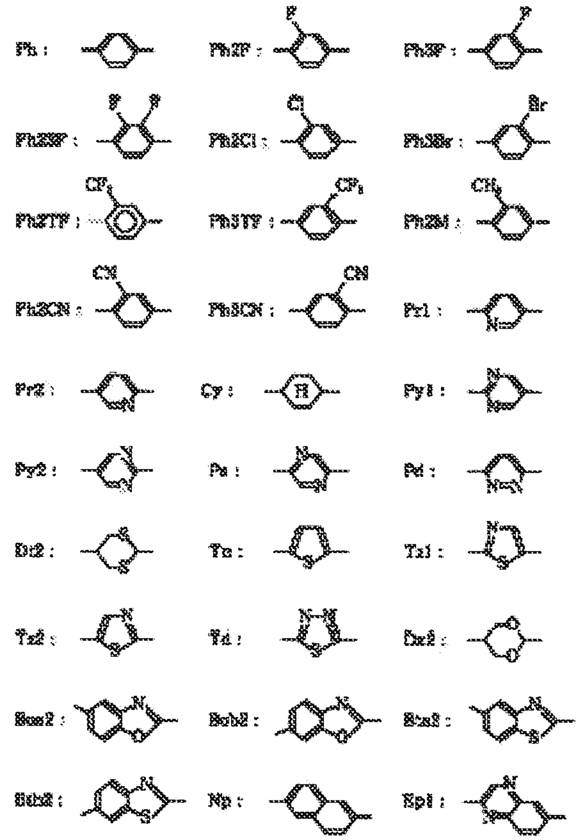


[0040]

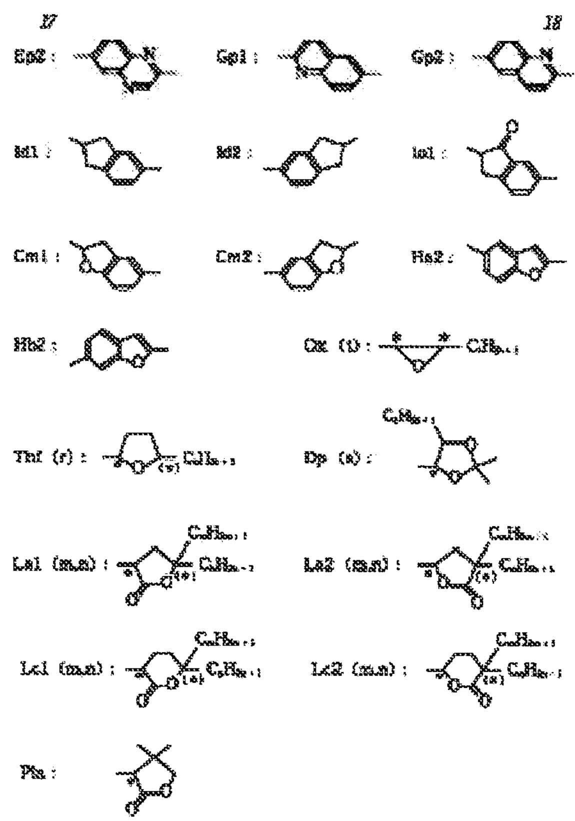
(R_3 and R_4 are stable under the synthesis conditions of the oxazolidinone ring, and are groups that can be converted to R_1 and R_2, and A_1 and A_2 are the same as defined above).

[0041] Specific structural formulas for the optically active compounds represented by general formula (I) are presented below. The designations used in the present invention denote the following groups.

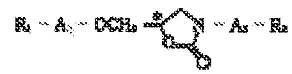
[0042]


Ph :
Ph2F :
Ph3F :
Ph23F :
Ph2Cl :
Ph3Br :
Ph2TF :
Ph3TF :
Ph2M :
Ph2CN :
Ph3CN :
Pr1 :
Pr2 :
Cy :
Py1 :
Py2 :
Pz :
Pd :
Dt2 :
Tn :
Tz1 :
Tz2 :
Td :
Dx2 :
Boa2 :
Bob2 :
Bta2 :
Btb2 :
Np :
Ep1 :

[0043]


Ep2 :
Gp1 :
Gp2 :
Id1 :
Id2 :
Io1 :
Cm1 :
Cm2 :
Ha2 :
Hb2 :
Ox (t) :
Thf (r) :
Dp (s) :
La1 (m,n) :
La2 (m,n) :
Lc1 (m,n) :
Lc2 (m,n) :
Pla :

[0044]



No.	R_1	A_1	A_2	R_2
1	C_5H_{11}	Ph	Ph	H
2	C_5H_{11}	Ph	Ph	OCH_3
3	$C_8H_{17}O$	Ph2F	Ph	$OCOC_3H_7$
4	$C_8H_{17}COO$	Ph	Ph	C_6H_{13}
5	$C_6H_{13}\overset{F}{\overset{\mid}{C}}HCH_2O$ *	Ph2F	Ph	C_8H_{17}
6	$C_7H_{15}O$	Ph3Br	Ph	$COOC_{10}H_{21}$
7	C_6H_{13}	Ph	Ph	$OC_{10}H_{21}$
8	$C_{10}H_{21}O$	Ph	Ph3F	$OC_{10}H_{21}$
9	C_5H_{11}	Ph	Ph	OC_5H_{11}
10	$C_{10}H_{21}$	Ph	Ph	$C_{10}H_{21}$
11	C_6H_{13}	Ph	Ph3F	$OCOC_4H_9$
12	$C_8H_{17}OCO$	Ph	Ph	$OCH_2CH_2\overset{CF_3}{\overset{\mid}{C}}HC_6H_{13}$ *
13	$C_7H_{15}O$	Ph23F	Ph	OC_6H_{13}
14	F	Ph	Ph	OC_9H_{19}
15	F	Ph2F	Ph	OC_9H_{19}
16	C_6H_{13}	Py1	Ph	C_6H_{13}
17	C_6H_{13}	Py1	Ph	$OC_{10}H_{21}$
18	$C_{10}H_{21}O$	Py2	Ph	$C_{10}H_{21}$
19	$C_{10}H_{21}$	Py2	Ph	$C_{10}H_{21}$
20	$C_6H_{13}OC\overset{CH_3}{\overset{\mid}{H}}CH_2O$ *	Py1	Ph	C_6H_{13}

[0045]

No.	R_1	A_1	A_2	R_2
21	$\begin{array}{c}F\\ \vert\\ C_6H_{13}CHCH_2CH_2O\\ *\end{array}$	Py1	Ph	OC_8H_{17}
22	$C_8H_{17}O$	Py2	[illegible]	C_8H_{17}
23	C_8H_{17}	Py2	Ph	Cl
24	C_8H_{17}	Pa	Ph	$\begin{array}{c}F\\ \vert\\ OCOCHC_6H_{13}\\ *\end{array}$
25	$C_9H_{19}O$	Pa	Ph3F	OC_6H_{13}
26	C_8H_{17}	Pa	Ph	C_9H_{19}
27	$C_8H_{17}O$	Pd	Ph	OC_8H_{17}
28	$C_6H_{13}COO$	Pd	Ph3F	$C_{10}H_{21}$
29	$\begin{array}{c}CH_3\\ \vert\\ C_2H_5CHCH_2\\ *\end{array}$	Pd	Ph	$\begin{array}{c}CF_3\\ \vert\\ OCH_2CH_2CHC_6H_{13}\\ *\end{array}$
30	C_8H_{17}	Cy	Ph	OC_6H_{13}
31	C_8H_{17}	Cy	Ph	$\begin{array}{c}\quad CH_3 \qquad\qquad\qquad CH_3\\ OCH_2CH_2CHCH_2CH_2CH=C-CH_3\end{array}$
32	C_8H_{17}	Cy	Ph3F	$OCOC_7H_{15}$
33	C_8H_{17}	Ph	Py1	C_8H_{17}
34	$\begin{array}{c}F\\ \vert\\ C_6H_{13}CHCH_2O\\ *\end{array}$	Ph	Py1	C_7H_{15}
35	$C_{10}H_{21}O$	Ph2F	Py1	$OC_{10}H_{21}$
36	C_8H_{17}	Ph	Py2	C_8H_{17}
37	$C_{10}H_{21}O$	Ph	Py2	$C_{10}H_{21}$
38	$C_8H_{17}O$	Ph3F	Py2	$C_{10}H_{21}$
39	$C_8H_{17}O$	Ph	Pa	$OCH_2C\equiv CH$
40	$C_6H_{13}OCO$	Ph	Pa	OC_6H_{13}

[0046]

No.	R_1	A_1	A_2	R_2
41	$C_6H_{13}OCH_2CH_2O$	Ph	Pd	$OC_{[illegible]}H_{[illegible]}$
42	$C_{[illegible]}H_{[illegible]}O$	Ph2Cl	Pd	$C_{[illegible]}H_{17}$
43	$C_{[illegible]}H_{[illegible]}O$	Ph	Tz	$C_{[illegible]}H_{[illegible]}$
44	$C_{[illegible]}H_{[illegible]}O$	Ph2F	Tz	$C_{[illegible]}H_{[illegible]}$
45	$C_{[illegible]}H_{[illegible]}$	Ph	Tz	$C_{[illegible]}H_{17}$
46	$C_{[illegible]}H_{[illegible]}$	Ph	Tz1	$C_{[illegible]}H_{[illegible]}$
47	$C_{[illegible]}H_{[illegible]}O$	Ph2M	Tz1	$C_{[illegible]}H_{[illegible]}$
48	$C_{[illegible]}H_{[illegible]}$	Ph	Tz1	$C_{[illegible]}H_{[illegible]}$
49	$C_{[illegible]}H_{[illegible]}$	Ph	Tz2	$C_{[illegible]}H_{[illegible]}$
50	$C_{[illegible]}H_{[illegible]}$	Ph	Tz2	$C_{[illegible]}H_{[illegible]}$
51	$C_{[illegible]}H_{[illegible]}O$	Ph	Tz2	$C_{[illegible]}H_{[illegible]}$
52	$C_{[illegible]}H_{[illegible]}$	Ph	Td	$C_{[illegible]}H_{[illegible]}$
53	$C_{[illegible]}H_{[illegible]}O$	Ph	Td	$C_{[illegible]}H_{[illegible]}$
54	$C_{[illegible]}H_{[illegible]}O$	Ph	Id2	$C_{[illegible]}H_{[illegible]}$
55	$C_{[illegible]}H_{[illegible]}$	Ph	Id2	$C_{[illegible]}H_{[illegible]}$
56	$C_{[illegible]}H_{[illegible]}$	Ph	Cm2	$C_{[illegible]}H_{[illegible]}$
57	$C_{[illegible]}H_{[illegible]}O$	Ph	Cm2	$C_{[illegible]}H_{[illegible]}$
58	$C_{[illegible]}H_{[illegible]}$	Ph	Bxz2	$C_{[illegible]}H_{[illegible]}$
59	$C_{[illegible]}H_{[illegible]}$	Ph2CN	Bxz2	$C_{[illegible]}H_{[illegible]}$
60	$C_{[illegible]}H_{[illegible]}O$	Ph	Btz2	$C_{[illegible]}H_{[illegible]}$
61	$C_{[illegible]}H_{[illegible]}$	Ph	Btz2	$C_{[illegible]}H_{[illegible]}$
62	$C_{[illegible]}H_{[illegible]}O$	Ph2Cl	Bzh2	$C_{[illegible]}H_{[illegible]}$
63	$C_{[illegible]}H_{[illegible]}$	Ph	Bzh2	$C_{[illegible]}H_{[illegible]}$
64	$CH_3OCH(CH_3)\text{-}(CH_2)_{[illegible]}\text{-}O$	Ph	Bzh2	$C_{[illegible]}H_{[illegible]}$

[0047]

No.	R_1	A_1	A_2	R_2
65	C_6H_{13}	Ph	Bth2	C_6H_{13}
66	$C_6H_{13}O$	Ph	Np	OC_5H_{11}
67	C_8H_{17}	Ph	Np	$C_{10}H_{21}$
68	C_6H_{13}	Ph	Np	$OCH_2\overset{F}{C}HC_2H_5$ *
69	$CH_2=CHCH_2O$	Ph	Np	$COC_{10}H_{21}$
70	$C_6H_{13}O$	Ph	Ep1	C_6H_{13}
71	$C_{10}H_{21}$	Ph	Ep1	$C_{10}H_{21}$
72	C_6H_{13}	Ph	Ep2	C_6H_{13}
73	C_8H_{17}	Ph	Ep2	C_6H_{13}
74	$C_6H_{13}O$	Ph2F	Gp1	OC_6H_{13}
75	$C_{10}H_{21}$	Ph	Gp1	C_6H_{13}
76	$C_5H_{11}O$	Ph	Gp1	$OCOCH_2\overset{CH_3}{C}HC_2H_5$ *
77	C_6H_{13}	Ph	Gp2	C_6H_{13}
78	C_6H_{13}	Ph	Gp2	OC_6H_{13}
79	C_6H_{13}	Dx1	Ph	OC_6H_{13}
80	$C_{10}H_{21}$	Dx1	Ph	$C_{10}H_{21}$
81	C_6H_{13}	Tz1	Ph	$C_{10}H_{21}$
82	C_6H_{13}	Tz2	Ph	$OCOC_6H_{13}$
83	C_6H_{13}	Boa1	Ph	C_6H_{13}
84	C_6H_{13}	Btb1	Ph	OC_6H_{13}
85	C_6H_{13}	Bta1	Ph	OC_5H_{11}
86	$C_{10}H_{21}$	Bth1	Ph	C_6H_{13}
87	$C_5H_{11}O$	Np	Ph	OC_5H_{11}

[0048]

No.	R_1	A_1	A_2	R_2
88	C_4H_9O	Np	Ph	$C_{10}H_{21}$
89	F $C_6H_{13}CHCH_2O$ *	Np	Ph	$OC_{10}H_{21}$
90	C_4H_9O	Ep1	Ph	C_8H_{17}
91	C_6H_{13}	Ep2	PhF	OC_8H_{17}
92	C_9H_{19}	Gp1	Ph	C_8H_{17}
93	$C_{10}H_{21}$	Gp2	Ph	SC_8H_{17}
94	C_8H_{17}	Cy	Pr1	C_8H_{17}
95	C_6H_{13}	Cy	Pr2	$C_{10}H_{21}$
96	$C_{10}H_{21}$	Cy	Py1	OCH[illegible] (S,S)
97	C_6H_{13}	Cy	Py2	C_6H_{13}
98	C_8H_{17}	Dx1	Pr1	OC_6H_{13}
99	$C_{10}H_{21}$	Dx1	Pr2	C_6H_{13}
100	C_6H_{13}	Dt1	Ph	C_8H_{17}
101	$C_{10}H_{21}$	Dt2	Pd	C_6H_{13}
102	$C_{10}H_{21}$	Cy	Np	OC_6H_{13}
103	C_8H_{17}	Cy	Md2	C_6H_{13}
104	C_6H_{13}	Cy	Cm2	C_8H_{17}
105	$C_{10}H_{21}$	Cy	Btb2	C_6H_{13}
106	$C_{10}H_{21}$	Py2	Np	$OC_{10}H_{21}$
107	C_6H_{13}	Py2	Cn2	C_6H_{13}
108	C_6H_{13}	Py2	Pr1	$C_{10}H_{21}$
109	$C_7H_{15}O$	Pd	Pr2	OC_7H_{15}
110	C_6H_{13}	Pd	Np	$C_{10}H_{21}$
111	$C_{10}H_{21}S$	Ph	Tn	C_8H_{17}

[0049]

No.	R_1	A_1	A_2	R_2
112	$C_6H_{13}O$	Pa	Tz2	C_6H_{13}
113	C_7H_{15}	Ph	Ph	OC_8H_{17}
114	Ox (S) - COO	Ph	Ph	OC_8H_{17}
115	C_8H_{17}	Ph	Hx2	C_6H_{13}
116	C_4H_9	Cm1	Ph	OCOThf (S)
117	C_6H_{13}	Cy	Np	OCH_2La1 (1,3)
118	$C_{10}H_{21}$	Ph3CN	Hx2	C_6H_{13}
119	$C_8H_{17}O$	Gp1	Ph	COOLa1 (S,R)
120	$C_{10}H_{21}COO$	Np	Ph3TF	OCH_2Ph
121	C_9H_{19}	Ph	Ph23F	OC_2H_5
122	C_5H_{11}	Cy	Ph	OCO - Ox (S)
123	$C_{10}H_{21}O$	Ph	Ph	OCH_2La2 (1,3)
124	Thf (R) COO	Ph	Ph	OC_8H_{17}
125	$PhCH_2O$	Ph2F	Ph	$COOC_3H_7$
126	Dp (S) CH_2O	Ph	Ph	$OCH_2\overset{CH_3}{\overset{\vert}{C}}HOC_5H_{11}$ *
127	La1 (1,3) CH_2O	Ep2	Ph	C_6H_{13}
128	$C_{10}H_{21}O$	Ph	Ph3CN	OC_8H_{17}
129	La2 (3,8) CH_2O	Ph	Np	COC_6H_{13}
130	$C_{10}H_{21}O$	Ph	Ph	C_6H_{13}
131	La3 (1,8) CH_2O	Ph	Id2	C_5H_{11}
132	C_6H_{13}	Ph	Ph	$C_8H_{17}O$
133	La2 (S,S) CH_2O	Ph	Btn2	C_7H_{15}
134	C_8H_{17}	Io1	Ph	OC_8H_{17}
135	$C_3F_7CH_2O$	Ph	Ph	C_6H_{13}

[0050]

No.	R_1	A_1	A_2	R_2
136	C_8H_{17}	Ph	Ph	$O-(CH_2)_3C_4F_9$
137	$C_4F_9OCF_2CH_2O$	Ph	Ph	OC_6H_{13}
138	$C_8H_{17}O$	Ph	Ph	$OCH_2CF_2O-(CF_2)_2OC_4F_9$
139	C_8H_{17}	Ph	Py1	$OCH_2C_4F_9$
140	$C_4F_9O-(CF_2)_2OCF_2CH_2O-$	Ph	Py1	$OC_{10}H_{21}$
141	$C_8H_{17}O$	Ph	Ph	$OCH_2C_4F_9$
142	C_8H_{17}	Ph	Py2	$OCH_2CF_2OC_4F_9$
143	$C_{10}H_{21}O$	Pd	Ph	$O-(CH_2)_3C_4F_9$
144	$C_8H_{17}O$	Pa	Ph	$OCH_2CF_2O-(CF_2)_2OC_4F_9$
145	$C_4F_9-(CH_2)_3O$	Pd	Ph	C_6H_{13}
146	$C_4F_9OCF_2CH_2O$	Ph	Gp1	OC_8H_{17}

[0051] The liquid crystal composition of the present invention can be obtained by mixing at least one type of the optically active compound represented in general formula (I) above at an appropriate ratio with one or more other types of liquid crystal compound. The

number of other liquid crystal compounds that are used in conjunction is 1-50, with 1-30 being preferred and 3-30 being additionally desirable.

[0052] In addition, the liquid crystal composition of the present invention is a ferroelectric liquid crystal composition, and ferroelectric chiral smectic liquid crystal compositions are preferred.

[0053] Examples of other liquid crystal compounds used in the present invention that may be cited are compounds (III) to (XII) described on pp. 23-39 of Japanese Unexamined Patent Application No. Hei 4[1992]-272989, with compounds (IIIa) to (XIId) being preferred, and compounds (IIIaa) to (XIIdb) being additionally desirable. Additional examples are compounds wherein at least one of R'_1 and R'_2 in compounds (III) to (VI), preferably compounds (IIIa) to (VIf) and more preferably compounds (IIIaa) to (VIfa); or wherein at least one of R'_3 and R'_4 in compounds (VII) and (VIII), preferably compounds (VIIa) to (VIIIb) and more preferably compounds (VIIIba) and (VIIIbb); or wherein at least one of R'_5 and R'_6 in compounds (IX) to (XII), preferably compounds (IXa) to (XIId), and more preferably compounds (IXba) and (XIIdb), is $-(CH_2)_E C_G F_{2G+1}$ (where E is 0-10 and G is an integer of 1-15). In addition, the liquid crystal compounds represented by general formulas (XIII) to (XVIII) may also be used.

[0054]

$R'_7 - X'_6 - [PyZ] - X'_7 - [Ph] - X'_8 - ([PhY'_x])_n - [Tn] - R'_8$ (XIII)

$R'_7 - X'_6 - [PyZ] - [Ph] - OCO - [Ph4F]$ (XIV)

$R'_7 - X'_6 - [PyZ] - [Ph] - OCO - [Ph34F]$ (XV)

$R'_7 - ([PhY'_7])_q - [Tz1] - [PhY'_8] - X'_6 - ([PhY'_9])_q - ([Cy])_r - X'_9 - R'_8$ (XVI)

$R'_7 - [Bo2] - A'_1 - X'_9 - R'_8$ (XVII)

$R'_7 - [Dt2] - A'_1 - X'_9 - R'_8$ (XVIII)

[0055] R'_7 and R'_8 are hydrogen atoms or linear or branched alkyl groups with carbon numbers of 1-18, where one or two or more non-adjacent $-CH_2-$ groups excluding the $-CH_2$ groups bonded directly to X'_6 and X'_9 in the aforementioned alkyl groups may be substituted with -O-, -CO-, -OCO-, -COO-, -CH(CN)- or $-C(CN)(CH_3)-$.

[0056] In addition, R'_7 and R'_8 are preferably (i) to (vii).

[0057]

i) Linear alkyl groups with carbon numbers of 1-15

[0058]

ii)

$$-(CH_2)_p\underset{\displaystyle}{\overset{\displaystyle CH_3}{\overset{|}{C}}}HC_qH_{2q+1}$$

p: 0 or integers of 1-5, q: integers of 2-11; optically inert or active

iii)

$$-(CH_2)_r\overset{\displaystyle CH_3}{\overset{|}{C}}H(CH_2)_sOC_tH_{2t+1}$$

r: 0 or integers of 1-6, s: 0 or 1, t: integers of 1-14; optically inert or active

iv)

$$-\overset{\displaystyle CH_3}{\overset{|}{C}}HCOOC_wH_{2w+1}$$

w: integers of 1-15; optically inert or active

v)

$$-(CH_2)_A\overset{\displaystyle CN}{\overset{|}{C}}HC_BH_{2B+1}$$

A: 0 or integers of 1-2, B: integers of 1-15; optically inert or active

vi)

$$-(CH_2)_C\underset{\underset{\displaystyle CH_3}{|}}{\overset{\displaystyle CN}{\overset{|}{C}}}C_DH_{2D+1}$$

c: 0 or integers of 1-2, D: integers of 1-15; optically inert or active

vii)

$$-(CH_2)_E C_G F_{2G+1}$$

E: 0 or integers of 1-10, G: integers of 1-15

viii) –H

[0059] N, Q, R, T: 0 or 1

Y'_7, Y'_8, Y'_9: H or F

A'_4: Ph, Np

X'_6, X'_9: Single bond, -COO-, -OCO-, -O-

X'_7, X'_8: Single bond, -COO-, -OCO-, $-CH_2O-$, $-OCH_2-$

(XIIIa) may be cited as a preferred compound for (XIII).

[0060]

$R'_7-X'_6-$[Py2]–[Ph]–OCO–[Tn1]–R'_8 (XIIIa)

(XVIa) and (XVIb) may be cited as preferred compounds for (XVI).

[0061]

R'_7-[Tz1]–[Ph]–$X'_9-R'_8$ (XVIa)

R'_7-[PhY'$_7$]–[Tz1]–[PhY'$_8$]–$X'_9-R'_8$ (XVIb)

(XVIIa) and (XVIIb) may be cited as preferred compounds for (XVII).

[0062]

R'_7-[Boa2]–[Ph]–O–R'_8 (XVIIa)

R'_7-[Boa2]–[Np]–O–R'_8 (XVIIb)

(XVIIIa) to (XVIIIc) may be cited as preferred compounds for (XVIII).

[0063]

R'_7–[Btb2]–[Ph]–R'_8 (XVIIIa)

R'_7–[Btb2]–[Ph]–O–R'_8 (XVIIIb)

R'_7–[Btb2]–[NP]–O–R'_8 (XVIIIc)

(XVIaa) to (XVIbc) may be cited as preferred compounds for (XVIa) and (XVIb).

[0064]

R'_7–[Tz1]–[Ph]–O–R'_8 (XVIaa)

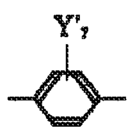
R'_7–[Ph]–[Tz1]–[Ph]–R'_8 (XVIba)

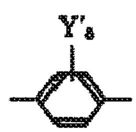
R'_7–[Ph]–[Tz1]–[Ph]–O–R'_8 (XVIbb)

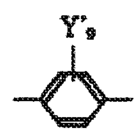
R'_7–[Ph]–[Tz1]–[Ph]–OCO–R'_8 (XVIbc)

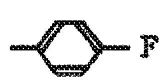
The symbols Ph, Py2, Tn, Tzl, Cy, Boa2 and Btb2 are in accordance with the aforementioned definitions, and other symbols denote the groups below.

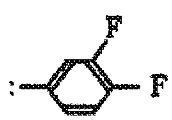
[0065]

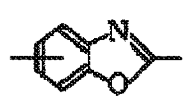
PhY'_7 : 

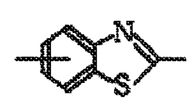
PhY'_8 : 

PhY'_9 : 

Ph4F : 

Ph34F : 

Bo2 : 

Bt2 : 

[0066] When mixing the optically active compounds of the present invention along with one or more types of the aforementioned liquid crystal compounds or liquid crystal compositions, the ratio of optically active compound of the present invention in the liquid crystal composition obtained by mixing them is preferably in the range of 1-80 wt%, depending on the combination of compounds that are used. In order to realize a ferroelectric liquid crystal element, it is necessary for the compound to satisfy various requirements such as liquid crystal properties over a broad temperature range, high-speed

response, high-contrast and constant switching. However, it is difficult to satisfy all of these conditions with a single compound, so the liquid crystal composition is commonly produced using various compounds that have advantages from various standpoints. In light of this, the ratio of optically active compound of the present invention in the liquid crystal compound is preferably 1-60 wt%, but 1-40 wt% is particularly desirable considering manifestation of the characteristics of the other constitutive liquid crystal compounds. If this amount is less than 1 wt%, then the effects of the compound of the present invention will be too small, and there is the possibility that good characteristics will not be obtained. When two or more types of the optically active compounds of the present invention are used, on the other hand, the mixing ratio of the two or more types of optically active compound of the present invention within the liquid crystal composition obtained by mixing them is 1-80 wt%. As stated above, the ratio is preferably 1-60 wt% in cases where a liquid crystal composition is produced that is composed of various types of compounds, but 1-40 wt% is preferred in consideration of manifesting the characteristics of the other constitutive liquid crystal compounds.

[0067] In addition, the ferroelectric liquid crystal layer in the ferroelectric liquid crystal element pertaining to the present invention is preferably obtained by using a liquid crystal composition comprising the optically active compound of the present invention prepared as described above, heating it in a vacuum to its isotropic liquid temperature, enclosing it in element cells, gradually cooling it to form a liquid crystal layer, and then returning it to normal pressure.

[0068] Figure 1 is presented in order to describe the constitution of a ferroelectric liquid crystal element. The figure is a schematic cross-sectional diagram that shows an example of a liquid crystal element with the ferroelectric liquid crystal layer of the present invention. The symbol **1** in Figure 1 denotes a ferroelectric liquid crystal layer, **2** denotes a glass substrate, **3** denotes a transparent electrode, **4** denotes an insulating alignment control layer, **5** denotes a spacer, **6** denotes a lead wire, **7** denotes a power source, **8** denotes a polarizing plate and **9** denotes a light source.

[0069] The two sheets of glass substrate **2** are coated with a transparent electrode **3** composed of a thin film of In_2O_3, SnO_2 or ItO (indium tin oxide). On top of this thin film, a polyimide or other similar macromolecular thin film is subjected to a rubbing treatment

with gauze, acetate flocked cloth or other such material in order to form an insulating alignment control layer **4** that is parallel to the direction in which the liquid crystal is rubbed. In addition silicon nitride, silicon carbide containing hydrogen, silicon oxide, boronitride, boronitride containing hydrogen, cerium oxide, aluminum oxide, zirconium oxide, titanium oxide, magnesium fluoride or other insulator may be used to form an inorganic insulating layer. Polyvinyl alcohol, polyimide, polyamide imide, polyester imide, polyparaxylene, polyester, polycarbonate, polyvinyl acetal, polyvinyl chloride, polyvinyl acetate, polyamide, polystyrene, cellulose resin, melamine resin, urea resin, acrylic resin photoresist resin or other organic insulator can then be formed thereupon to produce an alignment control layer. The insulating alignment control layer **4** may also be formed as two layers, and an inorganic insulating alignment control layer or organic insulating alignment control layer may also be formed in a single layer. This insulating alignment control layer can be formed by vapor deposition with inorganic systems. For organic systems, on the other hand, a solution produced by dissolving the organic insulating substance or a precursor solution thereof (0.1-20 wt% with respect to solvent, with 0.2-10 wt% being preferred) may be used, and the solution may be applied by a spin coating method, immersion coating method, screen printing method, spray coating method, roll coating method or the like. The layer can then be formed by curing the material under specified curing conditions (e.g., while heating). The layer thickness of the insulating alignment control layer **4** is normally 10 Å to 1 μm, with 10 Å to 3000 Å being preferred and 10-1000 Å being additionally desirable. The two glass substrates **2** are maintained at the desired gap using a spacer **5**. For example, silica beads or alumina beads having a prescribed diameter are sandwiched as spacers between the glass substrates **2**, and the perimeter is then sealed using a sealing agent such as epoxy-based adhesive. Macromolecular film or glass fiber may also be used as other spacers. Ferroelectric liquid crystal or, more specifically, the liquid crystal composition of the present invention is then enclosed between the two glass substrates as descried above.

[0070] The ferroelectric liquid crystal layer **1** formed by enclosing the ferroelectric liquid crystal is generally 0.5-20 μm, with 1-5 μm being preferred.

[0071] The transparent electrodes **3** are connected to an external power source **7** via a lead wire. In addition, polarizing plates **8** are affixed to the outside of the glass substrates **2**.

Figure 1 presents a transmissive device, and thus a light source **9** is provided. Figure 2 is a schematic drawing of an example cell used in order to describe the operation of the ferroelectric liquid crystal. **21a** and **21b** are substrates (glass plates) that are coated with a transparent electrode composed of a thin film such as In_2O_3, SnO_2 or ITO (indium tin oxide), where the liquid crystal molecule layer **22** present therebetween is produced by enclosing S^*_c phase or S^*_H phase liquid crystal oriented so that it is perpendicular with respect to the glass surface. The line **23** represented as a thick line denotes a liquid crystal molecule, and the liquid crystal molecule **23** has a dipole moment (P //symbol//) **24** in a direction orthogonal thereto. When a voltage that is greater than or equal to a constant threshold value is applied between the electrodes of the substrates **21a** and **21b**, the helical structure of the liquid crystal molecules **23** is eliminated, and the liquid crystal molecules **23** can change their direction of orientation so that all of the dipole moments (P//symb//) **24** align in the direction of the electrical field. The liquid crystal molecules **23** have a long narrow shape, and exhibit refractive index anisotropy in both the long and short axis directions. As a result, if crossed-Nicol polarizers are placed above and below the glass surfaces, it is easy to see that a liquid crystal optical modulation element can be produced wherein the optical characteristics change depending on the polarity of the applied voltage.

[0072] The liquid crystal cells that are preferably used as optical modulating elements in the present invention may be sufficiently thin (e.g., 10 μm or less). When the liquid crystal layer is made this thin, even when an electric field is not applied as shown in Figure 3, the helical structure of the liquid crystal molecule is undone, and the dipole moment Pa or Pb assumes a condition in which it is either upwards ((**34a**) or downwards (**34b**). In the type of cell shown in Figure 3, when electric fields **Ea** and **Eb** having different polarities that are at or above a constant threshold value are applied by voltage application means **31a** and **31b**, the dipole moment changes in the upwards direction **34a** or downwards direction **34b** in accordance with the electric field vector of the electric field **Ea** or **Eb**. In conjunction therewith, the liquid crystal molecules orient either in a first stable condition **33a** or a second stable condition **33b**.

[0073] As described above, the advantages of using this type of ferroelectric liquid crystal element as a light modulating element are twofold. Firstly, the response speed is extremely rapid, and secondly, the orientation of the liquid crystal molecules is bistable.

Considering the second advantage in additional detail in reference to Figure 3, for example, when an electric field **Ea** is applied, the liquid crystal molecules orient in the first stable condition **33a**, but this condition is stable even when the electric field is cut off. Moreover, when an electric field **Eb** is applied in the reverse direction, the liquid crystal molecules orient in the second stable condition **33b**, and although the direction of the molecules has changed, they remain in this state even when the electric field is cut off. In addition, if the electric field **Ea** or the electric field **Eb** does not reach a set threshold value, then the molecules will be maintained, of course, in the prior orientation condition.

[0074] Figure 5 is an example of the drive waveform used in the present invention. S_s in Figure 5A denotes the selected scanning waveform applied to the scanning lines that have been selected, S_N denotes the non-selected scanning waveform for the scanning lines that have not been selected, I_S denotes the selected data waveform (black) that is applied to the selected data lines, and I_N denotes the non-selected data signal (white) that is applied to the data lines that have not been selected. In the figures, $(I_S\text{-}S_S)$ and $(I_S\text{-}S_S)$ are voltage waveforms that are applied to the pixels on the scan lines that have been selected, and the pixels to which the voltage $(I_S\text{-}S_S)$ has been applied will assume a dark display state, whereas the pixels to which the voltage $(I_S\text{-}S_S)$ has been applied will assume a white display condition.

[0075] Figure 5(B) is a time series waveform for the drive waveform presented in Figure 5(A) when the display condition indicated in Figure 6 occurs. In the drive example presented in Figure 5, the minimum applied time Δt for the single polarity voltage applied to pixels on the selected scanning lines corresponds to the time of the writing phase t_2, and the time of the one-line clearing phase t_1 is set to $2\Delta t$. Thus, the values of the various parameters V_S, V_1 and Dt for the drive waveform presented in Figure 5 are defined by means of the switching characteristics of the liquid crystal material that is used. In this case, they are fixed at bias ratio $V_1/(V_1+V_S) = 1/3$. The range of the optimal drive voltage can be increased by increasing the bias ratio, but an increase in bias ratio means that the amplitude of the data signal increases, and in terms of image quality, flickering will increase and contrast will decrease, which is undesirable. In the investigations carried out by the authors, a bias ratio of about 1/3 to 1/4 has been practical.

[0076] A liquid crystal display device is realized by using the liquid crystal element of the present invention as a display panel component, and achieving communication synchronization using a data format comprising image information having scanning line address information and a SYNC signal as shown in Figure 7 and Figure 8.

[0077] The symbols used in the figures are represented below.

[0078] 101 Ferroelectric liquid crystal display device

102 Graphics controller

103 Display panel

104 Scanning line drive circuit

105 Data line drive circuit

106 Decoder

107 Scanning data generation circuit

108 Shift register

109 Line memory

110 Data signal generation circuit

111 Drive control circuit

112 GCPU

113 Host CPU

114 VRAM

[0079] Generation of image data is carried out by the graphics controller **102** in a main unit, and the data is transferred to a display panel **103** by means of the data transfer means presented in Figure 7 and Figure 8. The graphics controller **102** conducts management and communications for the image data between the host CPU **113** and liquid crystal display device **101** based on the CPU (central processing unit; referred to below as "GCPU 112") and VRAM (memory for video data storage) **114**. The control method of the present invention operates primarily based on the graphics controller **102**. A light source is disposed on the back surface of said display panel. Although the present invention is described in additional detail based on the working examples presented below, the present invention is not restricted to these working examples.

[0080]

[Working examples]

Working Example 1 (Synthesis of example compound no. 2)

(1) 10 mL of DMF was added to 2.00 g (13.3 mM) of 4-butylphenol, and the solution was stirred while chilling on ice water. 0.59 g (14.8 mM) of sodium hydride (60% oil) was added thereto. Next, 1.36 g (14.7 mM) of (R)-(-)-epichlorohydrin was added dropwise, and the mixture was additionally stirred at 60°C on an oil bath. After the reaction, the reaction system was poured into ice water, and sodium chloride was added, before extraction with ethyl acetate. After washing with saturated sodium chloride aqueous solution, the product was dried on anhydrous sodium sulfate. The sodium sulfate was then filtered out, and the solvent was then evaporated off to obtain 3.16 g of crude optically active 3-(4-butylphenoxy)-1,2-epoxypropane product.

[0081] (2) 1.50 g (6.30 mM) of optically active 3-(4-butylphenoxy)-1,2-epoxypropane, 0.008 g of lithium chloride and 3 mL of DMF were added, and stirred under reflux. 1 mL of DMF solution containing 0.95 g (6.37 mM) of 4-methoxyphenylisocyanate was added dropwise over a period of 30 min thereto, and the solution was stirred for 1 h upon completion of dropwise addition. After the reaction, the reaction system was poured into ice water, saturated sodium chloride solution was added, and the mixture was stirred at room temperature. The insoluble material was collected by filtration, and after washing with acetone, was subjected to silica gel column purification (running solvent: toluene/ethyl acetate: 100/1), whereupon the material was recrystallized from acetone to obtain 0.73 g of optically active compound corresponding to compound no. 2 (yield 32.6%).

[0082]

$$\text{Cryst} \underset{123}{\overset{140}{\rightleftarrows}} \text{Iso}$$

Phase transfer temperature (°C)

[0083] Working Example 2 (synthesis of example compound no. 113)

(1) 15.6 mL of methylene chloride was added to 20.65 g (1.83 mM) of example compound no. 2, the mixture was cooled while stirring on a dry ice-acetone bath, and 3.8 mL of a methylene chloride solution of 1.0 M boron tribromide was then added dropwise.

The cooling bath was removed, and stirring was continued for 3 h. The temperature was then increased to 17.5°C, the reaction solution was poured into cold water, saturated sodium chloride aqueous solution was added, and extraction was performed with ethyl acetate. After washing with saturated sodium chloride aqueous solution, the material was dried on anhydrous sodium sulfate. The sodium sulfate was then filtered out, and the solvent was removed to obtain 0.57 g of crude product of optically active 5-(4-butylphenyloxymethyl)-3-(4-hydroxyphenyl)-2-oxazolidinone.

[0084] (2) 0.30 g (0.88 mM) of optically active 5-(4-butylphenyloxymethyl)-3-(4-hydroxyphenyl)-2-oxazolidinone, 3.5 mL of DMF, 0.15 mL (1.02 M) of hexyl iodide and 0.04 g (1.00 mM) of sodium hydride (60% oil) were added, and the mixture was stirred for 30 min on an oil bath at a temperature of 70°C. After the reaction, the reaction system was poured into ice water, saturated salt was added, and the mixture was stirred at room temperature. The insoluble matter was collected by filtration and washed with water, before dissolving the product in toluene and drying the material on anhydrous sodium sulfate. After drying, the sodium sulfate was removed by filtration, and the solvent was evaporated off, before purification by silica gel column chromatography (running solvent: toluene/ethyl acetate = 20/1). The material was then recrystallized from acetone to obtain 0.2 g of optically active example compound no. 113 (yield 53.5%).

[0085]

$$\text{Cryst} \underset{103}{\overset{118}{\rightleftarrows}} \text{Iso}$$

Phase transfer temperature (°C)

[0086] Working Example 3

The following compounds were mixed in the weight ratios indicated below to produce a liquid crystal composition A.

[00087]

Chemical formula Parts by weight

C_9H_{19} – Py2 – Ph – OC_9H_{19}	8
$C_{10}H_{21}$ – Py2 – Ph – OC_8H_{17}	8
$C_8H_{17}O$ – Pr1 – Ph – O $(CH_2)_5$*CH (CH_3) C_2H_5	7
$C_{11}H_{23}O$ – Py2 – Ph – O $(CH_2)_2$*CH (CH_3) C_2H_5	1 4
$C_{10}H_{21}$ – Pr2 – Ph – C_6H_{13}	8
C_6H_{13} – Py2 – Ph – Ph – C_4H_9	4
C_8H_{17} – Ph – Pr2 – Ph – OC_5H_{11}	2
C_3H_7 – Cy – COO – Ph – Py1 – $C_{12}H_{25}$	1 0
C_5H_{11} – Cy – COO – Ph – Py1 – $C_{12}H_{25}$	5
$C_{10}H_{21}O$ – Ph – COS – Ph – OC_8H_{17}	1
C_6H_{13} – Ph – COO – Ph – Ph – OCH_2CH (CH_3) C_2H_5	7
C_3H_7 – Cy – CH_2O – Ph – Py1 – C_8H_{17}	7
$C_{10}H_{21}$ – Ph – Ph – OCH_2 – Ph – C_7H_{15}	5
$C_{12}H_{25}$ – Py2 – Ph – OCH_2 *CH (F) C_6H_{13}	2
C_5H_{11} – Cy – COO – Ph – OCH_2 *CH (F) C_6H_{13}	2
$C_{12}H_{25}O$ – Ph – Pa – COO $(CH_2)_3$*CH (CH_3) C_2H_5	2
$C_{12}H_{25}O$ – Ph – Pa – O $(CH_2)_3$*CH (CH_3) OC_3H_7	3

[0088] In addition, the example compounds presented below were mixed in the parts by weight indicated below with respect to the liquid crystal compound A to produce liquid crystal composition B.

[0089]

[Table 8]

	Parts by weight
Example compound no. 2	2
Example compound no. 8	1
Example compound no. 13	1
Liquid crystal composition A	96

[0090] Working Example 4

Two glass plates with thicknesses of 0.7 mm were used, and ITO films were formed on each of the glass plates. Voltage application electrodes were thus formed, and SiO_2 was then formed thereupon by vapor deposition as an insulating layer. An isopropyl alcohol solution containing 0.2% silane coupling agent (KBM-602; manufactured by Shin-

Etsu Chemical) was applied over a period of 15 sec with a spinner spinning at a rotation rate of 2000 rpm, thus carrying out surface treatment. Subsequently, the material was dried by heating for 20 min at 120 min. In addition, a dimethyl acetamide solution containing 1.5% of polyimide resin precursor (SP-510, manufactured by Toray) was then applied to the surface-treated glass plates with the ITO films over a period of 15 sec with a spinner at a rotation rate of 2000 rpm. After film formation, the material was subjected to a condensation baking treatment by heating at 300°C for 60 min. The film thickness of the coating at this time was bout 250 Å.

[0091] After this baking treatment, a rubbing treatment was carried out using acetate flocked cloth, and the material was washed with isopropyl alcohol. Silica beads with an average particle diameter of 2 μm were then distributed over one of the glass plates, and the glass plates were then affixed together using adhesive sealing agent (Lixon Bond; manufactured by Chisso Corp.) so that the rubbing axes were parallel. The material was then heated at 100°C for 60 min and was dried to produce a cell. The liquid crystal composition B mixed in Working Example 3 was then injected into the cell in an isotropic liquid state, and was cooled slowly to 25°C at 20°C/h from its isotropic phase, thus producing a ferroelectric liquid crystal element. The cell thickness of the cell was measured using a Berek compensator and was found to be about 2 μm. This ferroelectric liquid crystal element was then subjected to a peak-to-peak voltage V_{pp} of 20 V, the optical response (change in transmissive light flux 0-90%) under cross-Nicol polarizers was determined, and the response speed was measured (referred to below as "optical response speed"). The results are presented below.

[0092]

[Table 9]

Temperature	10°C	25°C	40°C
Response speed	473 μsec	245 μsec	139 μsec

[0093] Comparative Example 1

With the exception that the liquid crystal composition A mixed according to Working Example 3 was injected into the cell, a ferroelectric liquid crystal element was

produced by exactly the same method as in Working Example 4. The optical response speed was measured, and the results are presented below.

[0094]

[Table 10]

Temperature	10°C	25°C	40°C
Response speed	668 μsec	340 μsec	182 μsec

[0095]

Working Example 5

A liquid crystal composition C was produced by mixing the example compounds presented below instead of the example compounds used in Working Example 3 in the numbers of parts by weight shown below for each.

[0096]

[Table 11]

	Parts by weight
Example compound no. 3	1
Example compound no. 15	1
Example compound no. 22	2
Liquid crystal composition A	96

[0097] With the exception that the liquid crystal composition C was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0098]

[Table 12]

Temperature	10°C	25°C	40°C
Response speed	456 μsec	239 μsec	135 μsec

[0099]

Working Example 6

A liquid crystal composition D was produced by mixing the example compounds presented below instead of the example compounds used in Working Example 3 in the numbers of parts by weight shown below for each.

[0100]

[Table 13]

	Parts by weight
Example compound no. 5 Example compound no. 25 Example compound no. 36	1 1 2
Liquid crystal composition A	96

[0100] With the exception that the liquid crystal composition D was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0102]

[Table 14]

Temperature	10°C	25°C	40°C
Response speed	413 μsec	216 μsec	121 μsec

[0103] Working Example 7

The following compounds were mixed in the parts by weight indicated below to produce a liquid crystal composition E.

[0104]

Structural formula Parts by weight

$C_7H_{15}-Py2-Ph-OC_6H_{13}$	12
$C_{11}H_{23}-Py2-Ph-OC_6H_{13}$	1
$C_8H_{17}-Pr2\ \ Ph\ \ O(CH_2)_5{}^*CH(CH_3)C_2H_5$	1
$C_{10}H_{21}-Py2-Ph-O(CH_2)_4CH(CH_3)OCH_3$	3
$C_8H_{17}-Py2-Ph-Ph-OC_6H_{13}$	8
$C_8H_{17}O-Ph-OCO-Np-OC_8H_{17}$	4
$C_3H_7-Cy-COO-Ph-Py1-C_{12}H_{25}$	6
$C_5H_{11}-Cy-COO-Ph-Py1-C_{11}H_{23}$	2
$C_5H_{11}-Cy-COO-Ph-Py1-C_{11}H_{23}$	8
$C_{10}H_{21}O-Ph-COO-Ph-OCH_2{}^*CH(CH_3)C_2H_5$	15
$C_4H_9-Cy-CH_2O-Ph-Py1-C_6H_{13}$	7
$C_5H_{11}-Cy-CH_2O-Ph-Py1-C_6H_{13}$	7
$C_8H_{17}O-Ph\ \ OCH_2-Ph-Ph-C_7H_{15}$	4
$C_6H_{13}{}^*CH(CH_3)O-Ph-COO-Ph-Ph-OCO{}^*CH(CH_3)OC_4H_9$	2
$C_{12}H_{25}-Py2-Ph-OCO{}^*CH(Cl){}^*CH(CH_3)C_2H_5$	2

[0105] In addition, the example compounds presented below were each mixed in this liquid crystal composition E in the parts by weight shown below, thus preparing a liquid crystal composition F.

[0106]

[Table 15]

	Parts by weight
Example compound no. 18	2
Example compound no. 24	1
Example compound no. 39	1
Liquid crystal composition E	96

[0107] With the exception that the liquid crystal composition F was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0108]

[Table 16]

Temperature	10°C	25°C	40°C
Response speed	445 μsec	224 μsec	129 μsec

[0109] Comparative Example 2

With the exception that the liquid crystal composition E mixed in Working Example 7 was injected into in the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the results of measurement are presented below.

[0110]

[Table 17]

Temperature	10°C	25°C	40°C
Response speed	784 μsec	373 μsec	197 μsec

[0111] Working Example 8

A liquid crystal composition G was produced by mixing the example compounds presented below instead of the example compounds mixed in Working Example 7 in the numbers of parts by weight shown below for each.

[0112]

[Table 18]

	Parts by weight
Example compound no. 19	2
Example compound no. 28	1
Example compound no. 41	1
Liquid crystal composition E	96

[0113] With the exception that the liquid crystal composition G was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was

observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0114]

[Table 19]

Temperature	10°C	25°C	40°C
Response speed	471 μsec	238 μsec	138 μsec

[0115] Application Example 9

A liquid crystal composition H was produced by mixing the example compounds presented below instead of the example compounds mixed in Working Example 7 in the numbers of parts by weight shown below for each.

[0116]

[Table 20]

	Parts by weight
Example compound no. 21	1
Example compound no. 33	2
Example compound no. 42	1
Liquid crystal composition E	96

[0117] With the exception that the liquid crystal composition H was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0118]

[Table 21]

Temperature	10°C	25°C	40°C
Response speed	443 μsec	225 μsec	131 μsec

[0119] Working Example 10

The following compounds were mixed in the parts by weight indicated below to produce a liquid crystal composition I.

[0120]

Structural formula	Parts by weight
$C_8H_{17}-Py2-Ph-OC_6H_{13}$	10
$C_8H_{17}-Py2-Ph-OC_9H_{19}$	5
$C_{10}H_{21}-Py2-Ph-OCOC_8H_{17}$	7
$C_{10}H_{21}-Py2-Ph-O(CH_2)_3CH(CH_3)OC_3H_7$	7
$C_{12}H_{25}-Py2-Ph-O(CH_2)_4CH(CH_3)OCH_3$	6
$C_5H_{11}-Py2-Ph-Ph-C_6H_{13}$	5
$C_7H_{15}-Py2-Ph-Ph-C_6H_{13}$	5
$C_4H_9-Cy-COO-Ph-Py1-C_{12}H_{25}$	8
$C_3H_7-Cy-COO-Ph-Py1-C_{10}H_{21}$	8
$C_8H_{17}O-Ph-COO-Ph-OC_5H_{11}$	20
$C_8H_{17}-Ph-COO-Ph-Ph-OCH_2CH(CH_3)C_2H_5$	5
$C_8H_{17}-Ph-OCO-Ph-Ph-{}^*CH(CH_3)OCOC_6H_{13}$	5
$C_6H_{13}-Ph-OCH_2-Ph-Ph-C_7H_{15}$	6
$C_{12}H_{25}-Py2-Ph-OCH_2{}^*CH(F)C_6H_{13}$	3

[0121] In addition, a liquid crystal composition J was produced by mixing the example compounds presented below in this liquid crystal composition I in the numbers of parts by weight shown below for each.

[0122]

[Table 22]

	Parts by weight
Example compound no. 35	1
Example compound no. 45	2
Example compound no. 53	2
Liquid crystal composition I	95

[0123] With the exception that the liquid crystal composition J was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0124]

[Table 23]

Temperature	10°C	25°C	40°C
Response speed	419 μsec	215 μsec	119 μsec

[0125] Comparative Example 3

With the exception that the liquid crystal composition I mixed in Working Example 10 was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the results of measurement are presented below.

[0126]

[Table 24]

Temperature	10°C	25°C	40°C
Response speed	653 μsec	317 μsec	159 μsec

[0127] Working Example 11

A liquid crystal composition K was produced by mixing the example compounds presented below instead of the example compounds mixed in Working Example 10 in the numbers of parts by weight shown below for each.

[0128]

[Table 25]

	Parts by weight
Example compound no. 12	1
Example compound no. 50	2
Example compound no. 61	2
Liquid crystal composition I	95

[0129] With the exception that the liquid crystal composition K was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0130]

[Table 26]

Temperature	10°C	25°C	40°C
Response speed	391 μsec	202 μsec	112 μsec

[0131] Application Example 12

A liquid crystal composition L was produced by mixing the example compounds presented below instead of the example compounds mixed in Working Example 10 in the numbers of parts by weight shown below for each.

[0132]

[Table 27]

	Parts by weight
Example compound no. 66 Example compound no. 94 Example compound no. 112	1 1 2
Liquid crystal composition I	96

[0133] With the exception that the liquid crystal composition L was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 4. The optical response speed was measured, and the switching condition was observed. Uniform alignment in this liquid crystal element was favorable, and a monodomain condition was obtained. The results of measurement are presented below.

[0134]

[Table 28]

Temperature	10°C	25°C	40°C
Response speed	443 μsec	225 μsec	125 μsec

[0135] As is clear from Working Examples 4-12, the ferroelectric liquid crystal elements containing liquid crystal compositions B, C, D, F, G, H, J, K and L according to the present invention had improved operating characteristics and high-speed response. In addition, the elements had reduced dependence of optical response speed on temperature.

[0136] Working Example 13

An aqueous solution containing 2% of polyvinyl alcohol resin (PVA-117; manufactured by Kuraray) was used instead of the dimethyl actamide solution containing 1.5% of polyimide resin precursor used in Working Example 4. With this exception, a ferroelectric liquid crystal element was produced by exactly the same method, and the optical response speed was measured by the same method as in Working Example 4. The results are presented below.

[0137]

[Table 29]

Temperature	10°C	25°C	40°C
Response speed	475 μsec	244 μsec	139 μsec

[0138] Working Example 14

An alignment control layer was produced using only polyimide resin, without using the SiO_2 used in Working Example 4. With this exception, a ferroelectric liquid crystal element was produced by exactly the same method as in Working Example 4, and the optical response speed was measured by the same method as in the working examples. The results are presented below.

[0139]

[Table 30]

Temperature	10°C	25°C	40°C
Response speed	472 μsec	243 μsec	138 μsec

[0140] As is clear from Working Examples 13 and 14, even when the element structure was changed, the liquid crystal element containing the ferroelectric liquid crystal composition according to the present invention had dramatically improved low-temperature operating characteristics in the same manner as in Working Example 4, and a device was produced that had an optical response speed with little temperature dependence.

[0141] Working Example 15

The following compounds were mixed in the parts by weight indicated below to produce a liquid crystal composition M

[0142]

Structural formulas	Parts by weight
$C_8H_{17}-Py2-Ph-O(CH_2)_4C_3F_7$	5
$C_{11}H_{23}-Py2-Ph-OCH_2C_4F_9$	10
$C_8H_{17}O-Pr1-Ph-O(CH_2)_5CH(CH_3)C_2H_5$	5
$C_{10}H_{21}-Py2-Ph-O(CH_2)_6CH(CH_3)OCH_3$	10
$C_6H_{13}-Py2-Ph-Ph-C_8H_{17}$	7
$C_8H_{17}-Py2-Ph-OC_6H_{13}$	15
$C_6H_{13}-Cy-COO-Ph-Py1-C_{12}H_{25}$	5
$C_4H_9-Cy-COO-Ph-Py1-C_{11}H_{23}$	5
$C_3H_7-Cy-COO-Ph-Py1-C_{11}H_{23}$	5
$C_{12}H_{25}O-Ph-Pa-CO(CH_2)_3{}^*CH(CH_3)C_2H_5$	2
$C_{10}H_{21}-Py2-Ph-OCH_2{}^*CH(F)C_2H_5$	5
$C_6H_{13}-Cy-COO-Ph-OCH_2{}^*CH(F)C_6H_{13}$	2
$C_8H_{17}-Ph-COO-Ph-Ph-CH(CH_3)OCOC_6H_{13}$	6
$C_8H_{17}-Py2-Ph-OCO-Ph-F$	2
$C_7H_{15}O-Ph-Tz1-Ph-C_5H_{11}$	3
$C_6H_{13}O-Btb2-Ph-OCO(CH_2)_2C_4F_9$	3
$C_8H_{17}O-Ph-COS-Ph-OCH_2C_3F_7$	10

[0143] In addition, the example compounds indicated below were mixed with the liquid crystal composition M in the parts by weight indicated below for each, thus producing the liquid crystal composition N.

[0144]

[Table 31]

	Parts by weight
Example compound no. 29	1
Example compound no. 136	1
Example compound no. 139	1
Liquid crystal composition M	97

[0145] Optical response was observed in a cell produced by the procedure described below using these liquid crystal compositions.

[0146] Two sheets of glass plate with thicknesses of 0.7 mm were prepared, ITO films were formed on each of the glass plates to produce voltage application electrodes, and in addition, SiO_2 was vapor deposited thereupon to produce insulating layers. An isopropyl alcohol solution containing 0.2% of silane coupling agent (KBM-602, manufactured by Shin-Etsu Kagaku) was applied onto the glass plates using a spinner at a rotation rate of 2000 rpm for 15 sec, thus carrying out a surface treatment. Subsequently, the material was dried by heating for 20 min at 120°C. A dimethyl acetamide solution containing 1.0% of polyimide resin precursor (Toray SP-510) was then applied on the surface-treated glass plates with the ITO films using a spinner at a rotation rate of 3000 rpm for 15 sec. After film formation, a condensation baking treatment was carried out by heating at 300°C for 60 min. The film thickness of the coating at this time was about 120 Å.

[0147] A rubbing treatment was then carried out on the baked coatings using acetate flocked cloth, and the material was then washed with isopropyl alcohol. Silica beads with an average particle diameter of 1.5 μm were then distributed over one of the glass plates, and the glass plates were then affixed together using adhesive sealing agent (Lixon Bond; manufactured by Chisso Corp.) so that the rubbing axes were parallel. The material was then heated at 100°C for 60 min and was dried to produce a cell. The cell thickness of the cell was measured using a Berek compensator and was found to be about 1.5 μm. Liquid

crystal composition M was then injected into this cell in an isotropic liquid condition, and was cooled gradually from the isotropic phase to 25°C at 20°C/h, thus producing a ferroelectric liquid crystal element. This ferroelectric liquid crystal element was used, and was driven at 30°C using the drive waveform (bias ratio = 1/3) shown in Figure 5 above. The contrast was measured, and was found to be 14.2.

[0148] Comparative Example 4

With the exception that the liquid crystal composition M mixed in Working Example 15 was injected into the cell, a ferroelectric liquid crystal element was produced by the same method as in Working Example 15. The contrast was measured when driven at 30°C using the same driving waveform, and the results gave a contrast of 8.1.

[0149] Working Example 16

A liquid crystal composition O was produced by mixing the example compounds presented below instead of the example compounds mixed in Working Example 15 in the numbers of parts by weight shown below for each.

[0150]

[Table 32]

	Parts by weight
Example compound no. 94	1
Example compound no. 95	1
Example compound no. 141	1
Liquid crystal composition M	97

[0151] With the exception that this liquid crystal composition was used, a ferroelectric liquid crystal element was produced by exactly the same method as in Working Example 15, and the contrast was measured when driven at 30°C using the same driving waveform as in Working Example 15. The results gave a contrast of 19.8.

[0152] Working Example 17

A liquid crystal composition P was produced by mixing the example compounds presented below instead of the example compounds mixed in Working Example 15 in the numbers of parts by weight shown below for each.

[0153]

[Table 33]

	Parts by weight
Example compound no. 89	1
Example compound no. 110	1
Example compound no. 121	1
Liquid crystal composition M	97

[0154] With the exception that this liquid crystal composition was used, a ferroelectric liquid crystal element was produced by exactly the same method as in Working Example 15, and the contrast was measured when driven at 30°C using the same driving waveform as in Working Example 15. The results gave a contrast of 18.1.

[0155] Working Example 18

A liquid crystal composition Q was produced by mixing the example compounds presented below instead of the example compounds mixed in Working Example 15 in the numbers of parts by weight shown below for each.

[0156]

[Table 34]

	Parts by weight
Example compound no. 5	1
Example compound no. 68	1
Example compound no. 145	1
Liquid crystal composition M	97

[0157] With the exception that this liquid crystal composition was used, a ferroelectric liquid crystal element was produced by exactly the same method as in Working Example 15, and the contrast was measured when driven at 30°C using the same driving waveform as in Working Example 15. The results gave a contrast of 17.8.

[0158] As is clear from Working Examples 15-18, the ferroelectric liquid crystal elements containing liquid crystal compositions N, O, P and Q according to the present invention had increased contrast during driving.

[0159] Working Example 19

An aqueous solution containing 2% of polyvinyl alcohol resin (PVA-117; manufactured by Kuraray) was used instead of the dimethyl actamide solution containing 1.0% of polyimide resin precursor used in Working Example 15. With this exception, a ferroelectric liquid crystal element was produced by exactly the same method as in Working Example 15, and the contrast when driven at 30°C was measured by exactly the same method as in Working Example 15. The results gave a contrast of 17.8.

[0160] Working Example 20

An alignment control layer was produced using only polyimide resin, without using the SiO_2 used in Working Example 15. With this exception, a ferroelectric liquid crystal element was produced by exactly the same method as in Working Example 15, and the contrast when driven at 30°C was measured by the same method as in Working Example 15. The results gave a contrast of 14.0.

[0161] Working Example 21

An NMP solution containing 1% of polyamide acid (LQ1802; manufactured by Hitachi Kasei) was used instead of the dimethylacetamide solution containing 1.0% polyimide resin precursor used in Working Example 15, and baking was carried out for 1 h at 270°C. With these exceptions, a ferroelectric liquid crystal element was produced by exactly the same method as in Working Example 15, and the contrast when driven at 30°C was measured by the same method as in Working Example 15. The results gave a contrast of 21.8.

[0162] As is clear from Working Examples 19, 20 and 21, even when the element structure was changed, the liquid crystal elements containing the ferroelectric liquid crystal compositions according to the present invention provided the same high contrast as in Working Example 15. When the driving waveform was changed and detailed investigations were carried out, it was determined that high contrast could be obtained with liquid crystal elements containing the ferroelectric liquid crystal compositions of the present invention.

[0163]

[Effect of the invention] The liquid crystal composition containing optically active compound of the present invention can be utilized by employing the ferroelectric properties present in the liquid crystal composition. The ferroelectric liquid crystal

element of the present invention that can be realized in this manner is a liquid crystal element that has favorable switching characteristics, high response speed, low temperature dependence of optical response speed, high contrast and other superior characteristics.

[0164] The display device produced by assembling together a light source, drive circuit and other elements along with the liquid crystal element of the present invention as the display element produces favorable device characteristics.

[Brief description of the figures]

[Figure 1] Schematic cross-sectional view of an example of a liquid crystal element produced using liquid crystal having a chiral smectic phase.

[Figure 2] Perspective view that schematically presents an example of an element cell, which is used for describing the function of the liquid crystal element that utilizes the ferroelectric properties present in the liquid crystal.

[Figure 3] Perspective view that schematically represents an example of an element cell, which is used for describing function of the liquid crystal element that utilizes the ferroelectric properties present in the liquid crystal.

[Figure 4] Explanatory diagram showing the tilt angle (θ)

[Figure 5] Waveform diagram for the driving method used with the liquid crystal element of the present invention.

[Figure 6] Schematic diagram of the display pattern produced during actual driving with the time sequence drive waveform presented in Figure 5(B).

[Figure 7] Block diagram showing a liquid crystal display device containing a liquid crystal element utilizing ferroelectric properties and a graphics controller.

[Figure 8] Video data communications timing chart between the liquid crystal display device and the graphics controller.

[Key]

1 Liquid crystal layer having a chiral smectic phase

2 Glass substrate

3 Transparent electrode

4 Insulating alignment control layer

5 Spacer

6	Lead wire
7	Power source
8	Polarizing plate
9	Light source
I_0	Incident light
I	Transmitted light
21a	Substrate
21b	Substrate
22	Liquid crystal layer having a chiral smectic phase
23	Liquid crystal molecules
24	Dipole moment (P //symbol//)
31a	Voltage application means
31b	Voltage application means
33a	First stable condition
33b	Second stable condition
34a	Upwards dipole moment
34b	Downwards dipole moment
Ea	Upwards electric field
Eb	Downwards electric field
101	Ferroelectric liquid crystal display device
102	Graphics controller
103	Display panel
104	Scanning line drive circuit
105	Data line drive circuit
106	Decoder
107	Scanning data generation circuit
108	Shift register
109	Line memory
110	Data signal generation circuit
111	Drive control circuit
112	GCPU

113 Host CPU

114 VRAM

[Figure 1]

1 Liquid crystal layer having a chiral smectic phase

2 Glass substrate

3 Transparent electrode

4 Insulating alignment control layer

5 Spacer

6 Lead wire

7 Power source

8 Polarizing plate

9 Light source

I_0 Incident light

I Transmitted light

[Figure 2]

21a Substrate

21b Substrate

22 Liquid crystal layer having a chiral smectic phase

23 Liquid crystal molecules

24 Dipole moment (P //symbol//)

[Figure 3]

33a First stable condition

33b Second stable condition

34a Upwards dipole moment

34b Downwards dipole moment

[Figure 4]

[Figure 5]

t_1 One line clearing phase

t_2 Write phase

[Figure 6]

[Figure 7]

102	Graphics controller
103	Display panel (1280 x 1120 dots)
104	Scanning line drive circuit
105	Data line drive circuit
106	Decoder
107	Scanning data generation circuit
108	Shift register
109	Line memory
110	Data signal generation circuit
111	Drive control circuit
112	GCPU
113	Host CPU
114	VRAM

Key:

1	Display data
2	Scan line address data
3	Data line
4	Transmission clock

Continued from font page:

(51) Int. Cl.6	Identification Nos.:	Internal Filing Nos.:	FI:	Tech. Ind.
C 07 D 43/12	241			

	417/04	263		
C 09 K	19/34			9279-4H
	19/54		B	9279-4H
G 02 F	1/13	500		

(72) Inventor: Shinishi Nakamura
Canon Corp.
30-2 Shimomaruko 3-chome, Ota-ku, Tokyo

(72) Inventor: Yoko Yamada
[same address]